Universal Journal of Mechanical Engineering 5(2): 25-34, 2017 http://www.hrpub.org
DOI: 10.13189/ujme.2017.050201

Experimental Analyses on Parabolic Solar Collector at Various Operating Conditions

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Abstract This research work is concerned with comparative experimental analyses performed on parabolic solar collector. It presents the experimental analyses on parabolic solar collector at various operating conditions. For this experimental work, parabolic solar collector was fabricated. Various comparisons have been done between mirror concentrator and aluminium sheet concentrator. Experimental readings have been taken at 12:30 PM and at 01:30 PM and then performance of the solar collector has been found. For performance analyses, different pipe materials have been selected like copper pipe, aluminium pipe, brass pipe and mild steel pipe as receiver pipes. And different fluids have been selected for analyses like water and antifreeze ethylene glycol (coolant) as working fluids. Flowing fluids outlet temperatures, heat transfer rates and instantaneous efficiencies have been found at various operating conditions and then best operating condition for solar collector has been identified. This experimental research work can be concluded as up to 92% instantaneous efficiency and 12.2ºC temperature difference between inlet-outlet temperatures are achieved with aluminium sheet collector but 1208.99 W heat transfer rate is found through mirror collector with copper pipe and coolant. After all experiments, calculations and graphs have been plotted, concluded that overall performance of fabricated solar collector with the aluminum sheet collector, copper pipe and coolant is the best.

Keywords Parabolic Solar Collector, Heat Transfer Rate, Instantaneous Efficiency, Outlet Temperature

List of Nomenclatures

$I_b R_b$ = *Instantaneous/hourly beam radiation on a surface (W/m²)*
L = *Length of the pipe (m)*
W = *Aperture width (m)*
m_f = *Mass flow rate of flowing fluids (kg/sec)*
C_p = *Specific heat of working fluid (J/KgK)*
Q_u = *Rate of heat transfer (W)*
η_{ib} = *Instantaneous efficiency*
T_s = *Surface temperature of absorber pipe (ºC)*
T_{fi} = *Inlet temperature of flowing fluid in absorber pipe (ºC)*
T_{fo} = *Outlet temperature of flowing fluid in absorber pipe (ºC)*
f = *focal point of parabola (m)*
K = *Thermal conductivity of tube material (W-m/K)*

1. Introduction

India is a developing country, occupies 2.41% of world's land. Here the most of the population lived in villages around 70%. It is too difficult to fulfill energy requirements of country. Village and remote areas presents, which do not have electricity yet. In that condition the non-conventional energy sources are the best, easy and economical. Hydro, wind and solar is the better options for energy. Solar energy is the best option according to climatic condition of India. Available all over without any cost, just need appliance to restore and use energy.

Solar energy is the major non-conventional source of energy. It is natural and free of cost without any kind of pollutants or harmful effect to the environment. Now in the 21st century the environment condition of the earth is too affected by fossil fuels which release gases to the atmosphere, cause of that living species on earth having very big problem to live healthy and long. Also the temperature of earth increases year by year .In the modern world the most required aspect is energy. However, the energy requirements of the world fulfilled but the non-conventional source of energy are having lack of technology and difficult to store and they are not economical. Whenever the research's done with non-conventional sources makes them economical. If people not aware of it and the important steps not taken now, then the source of conventional energies will lost in few years and whole world see the earth without energy. So this is time to look forward and work for the future, next generation will be thankful to us.

Solar energy is a green energy and will facilitate reduction in greenhouse affects. A lot of research works have been done on it by many researchers. Kumar K. V. P. et al [2] have done experimental studies on parabolic solar collector with Sun tracking mechanism. They have worked on improving performance of parabolic solar collector with tracking mechanism at different operating conditions and they found mirror collector performed well in dry weather condition than aluminium collector. Tzivanidis C. et al [3] have simulated parabolic solar collector with commercial software Solid works which can solve complicated problems in easy way. Efficiency of the collector, heat transfer rate and convective heat transfer coefficient has also been predicted from this model. Liu X. et al [4] have investigated effect on instantaneous efficiency by multi factors in cold environment. For this investigation, they have used Sol Trace software with CFD software. Mohamad A. et al [5] worked on thermal performance of the solar collector and identified different ways of heat loss from the collector. They have also found flowing fluids, pipe and glass temperatures at various conditions.

The parabolic collector is that type of thermal collector which is bent as parabola. The bent face has polished mirrors or polished aluminium sheet for reflection of heat energy on absorber or receiver pipe placed at focal length of parabola. Source and sink connected to the receiver pipe for working fluid flow. Rate of heat transfer depends on mass flow rate, controlled by valve given at outlet of receiver pipe.

Experimental comparison in research work would be applied here because parabolic solar concentrator of mirror is tough design in single piece and if it is fitted in small parts then the performance would be affected; that's why aluminium sheet parabolic concentrator are prepared and assembled for experiments. Aluminium sheet concentrator is easy to design and assemble, also easily available everywhere. Reflectivity for mirror is 1 and for Al polished sheet is 0.96. After that, receiver pipe materials are selected. Copper pipe is used for heat exchange device because thermal conductivity of copper is higher than aluminium, brass and mild steel. Thermal conductivity of various materials are - thermal conductivity for copper (K) is 386 Wm/K, thermal conductivity for aluminium (K) is 204 Wm/K, thermal conductivity for brass (K) is 116 Wm/K and thermal conductivity for mild steel (K) is 52 Wm/K. Performance of pipe materials also depend on its properties like transmissivity and absorptivity. These terms are important because sun rays reflect through collector to receiver pipe surface in the form of radiation. Working fluid used commonly water because of higher specific heat and its availability and used repeatedly but water is corrosive and having low boiling and low freezing point. Also scale formation and its cutting fluid properties make it lower valuable as working fluid. Coolant (antifreeze ethylene glycol) is used as working fluid because it is non-corrosive, having higher boiling point and antifreeze properties. Coolant is also non sticky and low friction fluid. Specific heat of water (C_p) is 4.186kJ/kgK and specific heat of coolant (C_p) is 2.481kJ/kgK. Layout of typical parabolic solar system is shown in figure 1. Figure 2 and figure 3 show two different solar collectors which have been used in experimental analyses.

Figure 1. Layout of parabolic solar system

Important parts of parabolic solar collector are shown in Figure 1 which is foundation supports, parabolic collector, receiver/absorber tube and rotational axis of collector.

Figure 2. Fabricated parabolic solar collector with polished mirror collector

Figure 2 shows polished mirror collector and the whole arrangement of the parabolic solar collector. Here the dimensions of the collector are (8 x 4 feet) and the pieces of the mirror pasted on the collector surface are (152.4 x 50.8 x 2 mm). Also length of receiver tube is 1.32 m. Bucket was used as source and fitted at some height from setup and valve is given at outlet to control flow rate.

Figure 3. Fabricated parabolic solar collector with polished aluminium sheet collector

The arrangement of parabolic solar collector shows a polished aluminium sheet served as the collector in Figure 3. Here the dimensions of the aluminium sheet collector are (8 x 4) feet and 18 gauge (1.2mm) thickness. Other arrangements are same as mirror collector.

Parabolic Solar Collector's Specifications are as Follows:

(1) Collector aperture area (A) is 2.486m^2,
(2) Collector aperture width (W) is 2.04 m,
(3) Aperture length (L) is 1.219m,
(4) Length of absorber pipe (l) is 1.321m,
(5) Inner and outer diameters of receiver pipe (D_i and D_o) 0.028m and 0.032m respectively,
(6) Aperture to length ratio 1.673,
(7) Mode of tracking North-South horizontal,
(8) Solar intensities at 12.30PM and 01.30PM is 526.90W/m^2 and 529.0W/m^2 respectively,
(9) Densities of water and antifreeze ethylene glycol (ρ_w and ρ_c) are 928kg/m^3 and 944kg/m^3 respectively and
(10) Specific heats for water and antifreeze ethylene glycol (C_w and C_c) are 4.186x10^{3}J/kg-K and 2.481x10^{3}J/kg-K respectively.

2. Methodology

Experiments have been performed with two collectors (namely made of polished mirror and Al sheet), two flowing fluids (water and antifreeze ethylene glycol) and four receiver/absorber pipes (Cu, Al, Br and MS). All readings have been taken under 526.90 W/m^2 and 529.0 W/m^2 solar intensities at 12:30 PM and 01:30 PM respectively [1]. Entire research analyses performed in the month of November, 2016 at Sushila Devi Bansal College of Technology, Indore, Madhya Pradesh, India (Latitude - 22°43'4.51"N and Longitude - 75°49'59.88"E). In this research analyses, 128 readings have been taken at different operating conditions and different combinations. Experiment procedure is followed as, the source (bucket) is filled with fluid (water or coolant) continuously and it flows through receiver pipe. The flow rate is controlled by valve which is located at outlet of receiver pipe. At outlet, discharge fluid is collected in a calibrated beaker of 250 ml. Then mass flow rate of flowing fluid is calculated. Readings are taken at four different flow rates with all combinations. After finding inlet/outlet temperatures, heat transfer rates and instantaneous efficiencies have been calculated. Following relations have been used to calculate heat transfer rate and instantaneous efficiency [1, 6].

Useful heat gain rate,

$$Q_u = m_f\, C_p\, (T_{fo} - T_{fi}) \qquad \text{Eq. (1)}$$

Instantaneous efficiency,

$$\eta_{ib} = (Q_u) / (I_b R_b\, W\, L) \qquad \text{Eq. (2)}$$

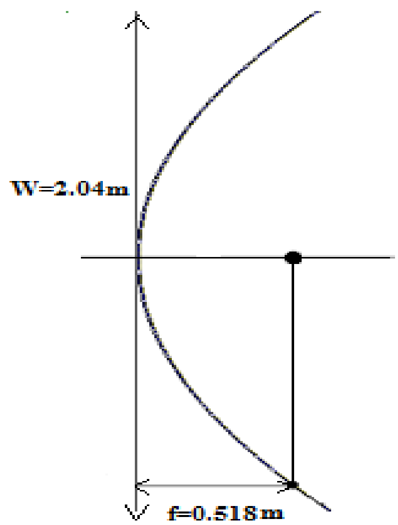

Figure 4. Graphical method to find focus point for parabolic solar collector

Figure 4 shows the schematic design of the parabolic collector and pertinent dimensions. It is simply drawn by graphical method according to our design dimensions and then found focal point. Here, W is width of parabola and f is focal point.

3. Results and Discussions

By number of experiments, following observations were found with the parabolic mirror concentrator and with aluminium sheet concentrator. For the absorber tube, four different materials copper, aluminium, brass and mild steel were used and two different flowing fluids water (density 928 kg/m^3) and antifreeze ethylene glycol (density 944 kg/m^3) were chosen for experiments. Readings of mirror and Al sheet concentrators have been shown parallel in tables 1 to 16 and experiments have been done with both concentrators at different dates. For example, table 1 shows the results of mild steel (receiver pipe) and water combination with both concentrators at 12:30 PM on 11 November 2016 and 22 November 2016 and table 2 shows the results of mild steel (receiver pipe) and antifreeze ethylene glycol combination with both concentrators at 12:30 PM. Same procedures have been followed for 01:30 PM with both concentrators and fluids on same dates. After mild steel pipe, Cu, Al and Br pipes were fitted as receiver tubes and same experimental procedures were followed repeatedly.

Table 1. 12: 30pm, I_bR_b = 526.9 W/m^2 (Mild steel-Water)

Concentrator/ Date	Mirror concentrator/ 11 Nov, Friday (T_a =26 °C)						Aluminium sheet concentrator/ 22 Nov , Tuesday (T_a =28 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0229	46	30	41	1054.45	80.47	0.0249	42	29	38	938.082	71.59
	0.0248	44	30.5	37	674.783	51.49	0.0207	41	29	36	606.551	25.94
	0.0418	43	31	37	1049.84	80.12	0.0401	40	29.5	35	923.222	21.37
	0.0246	41	31	34.5	360.414	27.50	0.0112	39	29.5	35	257.857	19.67

Table 2. 12: 30pm, I_bR_b = 526.9 W/m^2 (Mild steel-Antifreeze ethylene glycol)

Concentrator/ Date	Mirror concentrator/ 11 Nov, Friday (T_a =26 °C)						Aluminium sheet concentrator/ 22 Nov , Tuesday (T_a =28 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0131	40	28	35	227.507	17.36	0.0186	37	26	31.5	253.806	19.37
	0.0180	39.5	28	35	312.606	23.85	0.0412	37	26	32	613.303	46.80
	0.0207	39	29	35	308.140	23.51	0.0223	38	27	33.5	359.621	27.44
	0.0208	38	29	36	361.233	27.56	0.0208	35	27	33	309.628	23.63

Table 3. 01: 30pm, I_bR_b = 529 W/m^2 (Mild steel-Antifreeze ethylene glycol)

Concentrator/ Date	Mirror concentrator/ 11 Nov, Friday (T_a =28 °C)						Aluminium sheet concentrator/ 22 Nov , Tuesday (T_a =28 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0487	44	33	38	604.123	45.92	0.0213	44	31	40	475.607	36.15
	0.0336	43	33	39	500.169	38.02	0.0328	43	31	39.5	691.702	52.58
	0.0201	42	33	39	299.208	22.74	0.0157	42	31.5	39	292.138	22.20
	0.0310	41	33	39	461.466	35.07	0.0254	40	31.5	38	409.613	31.13

Table 4. 01: 30pm, I_bR_b = 529 W/m^2 (Mild steel-Water)

Concentrator/ Date	Mirror concentrator/ 11 Nov, Friday (T_a =28 °C)						Aluminium sheet concentrator/ 22 Nov , Tuesday (T_a =28 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0215	32	21	27	539.994	41.04	0.0197	37	29	33	329.856	25.07
	0.0337	31.5	21.5	26.5	705.341	53.61	0.0172	36	29	32.5	251.997	19.15
	0.0129	30	22	26	215.997	16.41	0.0211	35	30	32.5	220.812	16.78
	0.0151	30	22	26	252.834	19.22	0.0287	34	30	32	240.276	18.26

Table 5. 12: 30pm, I_bR_b = 526.9 W/m^2 (Copper-Water)

Concentrator/ Date	Mirror concentrator/ 12 Nov , Saturday (T_a =28 ^{o}C)						Aluminium sheet concentrator/ 17 Nov, Thursday (T_a =28 ^{o}C)					
Sr. No.	m_f (kg/sec)	T_s (^{o}C)	T_{fi} (^{o}C)	T_{fo} (^{o}C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (^{o}C)	T_{fi} (^{o}C)	T_{fo} (^{o}C)	Q_u (W)	η (%)
	0.0271	43	31	40	1020.96	77.92	0.0241	47	29	41.2	1230.77	93.93
	0.0049	42	31	38	143.579	10.95	0.0230	42	29	38	866.50	66.13
	0.0173	41	32	37	362.089	27.63	0.0120	41	29.5	38	426.97	32.58
	0.0429	41	32	36	718.317	54.82	0.0270	40	29.5	36	734.643	56.06

Table 6. 12: 30pm, I_bR_b= 526.9 W/m^2 (Copper-Antifreeze ethylene glycol)

Concentrator/ Date	Mirror concentrator/ 12 Nov , Saturday (T_a =28 ^{o}C)						Aluminium sheet concentrator/ 17 Nov, Thursday (T_a =28 ^{o}C)					
Sr. No.	m_f (kg/sec)	T_s (^{o}C)	T_{fi} (^{o}C)	T_{fo} (^{o}C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (^{o}C)	T_{fi} (^{o}C)	T_{fo} (^{o}C)	Q_u (W)	η (%)
	0.0565	40	29	34	700.882	53.49	0.0092	40	26	32	136.950	10.45
	0.0149	40	29.5	35	203.318	15.51	0.0136	40	26	32	202.449	15.45
	0.0365	39.5	30	35	452.782	34.55	0.0138	39	27	35	273.902	20.90
	0.0229	39	30	35	284.074	21.68	0.0190	38	27	36	424.251	32.37

Table 7. 01: 30pm, I_bR_b = 529 W/m^2 (Copper-Antifreeze ethylene glycol)

Concentrator/ Date	Mirror concentrator/ 12 Nov , Saturday (T_a = 30 ^{o}C)						Aluminium sheet concentrator/ 17 Nov, Thursday (T_a =29 ^{o}C)					
Sr. No.	m_f (kg/sec)	T_s (^{o}C)	T_{fi} (^{o}C)	T_{fo} (^{o}C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (^{o}C)	T_{fi} (^{o}C)	T_{fo} (^{o}C)	Q_u (W)	η (%)
	0.0343	44	28	39	936.081	71.15	0.0185	43	33.5	39	252.44	19.18
	0.0284	44	28.5	40	810.294	61.59	0.0123	43	33.5	39	167.83	12.75
	0.0109	42	29	39.5	283.950	21.58	0.0165	42	34	39	204.68	15.55
	0.0108	41	29	39	267.948	20.36	0.0147	41	34	39	182.354	13.86

Table 8. 01: 30pm, I_bR_b = 529 W/m^2 (Copper-Water)

Concentrator/ Date	Mirror concentrator/ 12 Nov , Saturday (T_a = 30 ^{o}C)						Aluminium sheet concentrator/ 17 Nov, Thursday (T_a =29 ^{o}C)					
Sr. No.	m_f (kg/sec)	T_s (^{o}C)	T_{fi} (^{o}C)	T_{fo} (^{o}C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (^{o}C)	T_{fi} (^{o}C)	T_{fo} (^{o}C)	Q_u (W)	η (%)
	0.0183	40	30	34	306.415	23.29	0.0203	39	30	34	339.903	25.83
	0.0080	40	30	34	133.952	10.18	0.0223	38	30	33	280.043	21.28
	0.0408	39	30	35	853.944	64.91	0.0314	37	30	34	525.761	39.96
	0.0305	38	31	34	383.019	29.11	0.0107	36	30	33	134.370	10.21

Table 9. 12: 30pm, I_bR_b = 526.9 W/m^2 (Aluminium-Water)

Concentrator/ Date	Mirror concentrator/ 14 Nov , Monday (T_a = 27 ^{o}C)						Aluminium sheet concentrator/ 18 Nov , Friday (T_a = 28 ^{o}C)					
Sr. No.	m_f (kg/sec)	T_s (^{o}C)	T_{fi} (^{o}C)	T_{fo} (^{o}C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (^{o}C)	T_{fi} (^{o}C)	T_{fo} (^{o}C)	Q_u (W)	η (%)
	0.0217	39	25	34	817.525	62.39	0.0288	44	32	42	1205.56	92.00
	0.0114	38	25.5	33.5	381.763	29.13	0.0219	43	32	40	733.387	55.97
	0.0192	37	26	34	642.969	49.07	0.0134	42	32.5	38	308.508	23.54
	0.0165	36	26	33	483.483	36.90	0.0280	41	32.5	37	527.436	40.25

Table 10. 12: 30pm, I_bR_b = 526.9 W/m^2 (Aluminium-Antifreeze ethylene glycol)

Concentrator/ Date	Mirror concentrator/ 14 Nov , Monday (T_a = 27 °C)						Aluminium sheet concentrator/ 18 Nov , Friday (T_a = 28 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0332	34	25	30	411.846	31.43	0.0192	37	25	31	285.811	21.81
	0.0182	33.5	25.5	29.5	180.616	13.78	0.0144	36	25	31	214.358	16.35
	0.0312	33	26	31	387.036	29.53	0.0087	35	26	33	151.092	11.53
	0.0276	32.5	26	30.5	308.140	23.51	0.0167	34	26	32.5	269.312	20.55

Table 11. 01: 30pm, I_bR_b = 529 W/m^2 (Aluminium-Antifreeze ethylene glycol)

Concentrator/ Date	Mirror concentrator/ 14 Nov , Monday (T_a = 30 °C)						Aluminium sheet concentrator/ 18 Nov , Friday (T_a = 28 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0191	41	30	37	331.709	25.21	0.0174	42	31.5	37	237.431	18.04
	0.0278	40	30	36.5	448.316	34.07	0.0206	41	31.5	36	229.988	17.48
	0.0291	39	31	37	433.182	32.92	0.0303	39	32	36	300.697	22.85
	0.0383	39	31	36	475.111	36.11	0.0196	38	32	36	194.510	14.78

Table 12. 01: 30pm, I_bR_b = 529 W/m^2 (Aluminium-Water)

Concentrator/ Date	Mirror concentrator/ 14 Nov , Monday (T_a = 30 °C)						Aluminium sheet concentrator/ 18 Nov , Friday (T_a = 28 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0227	33	23	29	570.1332	43.33	0.0210	37	29	32.5	307.671	23.38
	0.0144	33	24	27	180.8352	13.74	0.0119	36	29	32	149.440	11.35
	0.0337	32	24	28.5	634.8069	48.25	0.0295	35	30	33	370.461	28.16
	0.0106	31	24	28	177.4864	13.49	0.0346	35	30	33	434.506	33.02

Table 13. 12: 30pm, I_bR_b = 526.9 W/m^2 (Brass-Water)

Concentrator/ Date	Mirror concentrator/ 15 Nov , Tuesday (T_a = 27 °C)						Aluminium sheet concentrator/ 21 Nov , Monday (T_a = 30 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0158	44	31	40	595.249	45.42	0.0112	44	29	37.5	398.507	30.41
	0.0121	44	31	41.5	531.831	40.59	0.0215	43	29	39	899.990	68.68
	0.0203	43.5	32	38.5	552.342	42.15	0.0182	41	30	36.5	495.203	37.79
	0.0319	43	32	37	667.667	50.95	0.0223	39	30	36	560.086	42.74

Table 14. 12: 30pm, I_bR_b = 526.9 W/m^2 (Brass-Antifreeze ethylene glycol)

Concentrator/ Date	Mirror concentrator/ 15 Nov , Tuesday (T_a = 27 °C)						Aluminium sheet concentrator/ 21 Nov , Monday (T_a = 30 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0206	38	29	34	255.543	19.50	0.0301	38	25	32	522.746	39.89
	0.0198	38.5	29.5	34	221.057	16.87	0.0118	38.5	25	32	204.930	15.64
	0.0233	37	30	34	231.229	17.64	0.0200	37	26	33	347.340	26.50
	0.0184	36	30	34	182.601	13.93	0.0271	36	26	33	470.645	35.91

Table 15. 01: 30pm, I_bR_b = 529 W/m^2 (Brass-Antifreeze ethylene glycol)

Concentrator/ Date	Mirror concentrator/ 15 Nov , Tuesday (T_a = 30 °C)						Aluminium sheet concentrator/ 21 Nov , Monday (T_a = 28 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0138	42	33	39	205.426	15.61	0.0317	43	31	39	629.181	47.82
	0.0107	42	33	38.5	146.006	11.09	0.0287	40	31	37	427.228	32.47
	0.0139	41.5	33	38	172.429	13.10	0.0238	39	32	36.5	265.715	20.19
	0.0240	41.5	33	38	297.720	22.63	0.0187	37	32	36	182.602	13.88

Table 16. 01: 30pm, I_bR_b= 529 W/m^2 (Brass-Water)

Concentrator/ Date	Mirror concentrator/ 15 Nov , Tuesday (T_a = 30 °C)						Aluminium sheet concentrator/ 21 Nov , Monday (T_a = 28 °C)					
Sr. No.	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)	m_f (kg/sec)	T_s (°C)	T_{fi} (°C)	T_{fo} (°C)	Q_u (W)	η (%)
	0.0279	38	29	34	583.947	44.38	0.0339	36	29	32	425.716	32.36
	0.0138	38	29	33.5	259.950	19.76	0.0195	35.5	29	32	244.881	18.61
	0.0323	37.5	30	34	540.831	41.11	0.0214	35	29.5	32	223.951	17.02
	0.0148	37.5	30	34	247.811	18.837	0.0156	35	29.5	32	163.254	12.41

Some comparative results of heat transfer rates (HTRs) have also been shown in Figure 5 to 9. Figure 5 shows comparison of percentages of HTRs between mirror concentrator and aluminium sheet concentrator. Figure 6 shows comparison of percentages of HTRs between copper, aluminium, brass and mild steel materials with mirror concentrator. Figure 7 shows comparison of percentages of HTRs between copper, aluminium, brass and mild steel materials with aluminium sheet concentrator. Figure 8 shows comparison of percentages of HTRs between water and coolant as working fluids through receiver pipe with mirror concentrator. And, Figure 9 shows comparison of percentages of HTRs between water and coolant with aluminium concentrator.

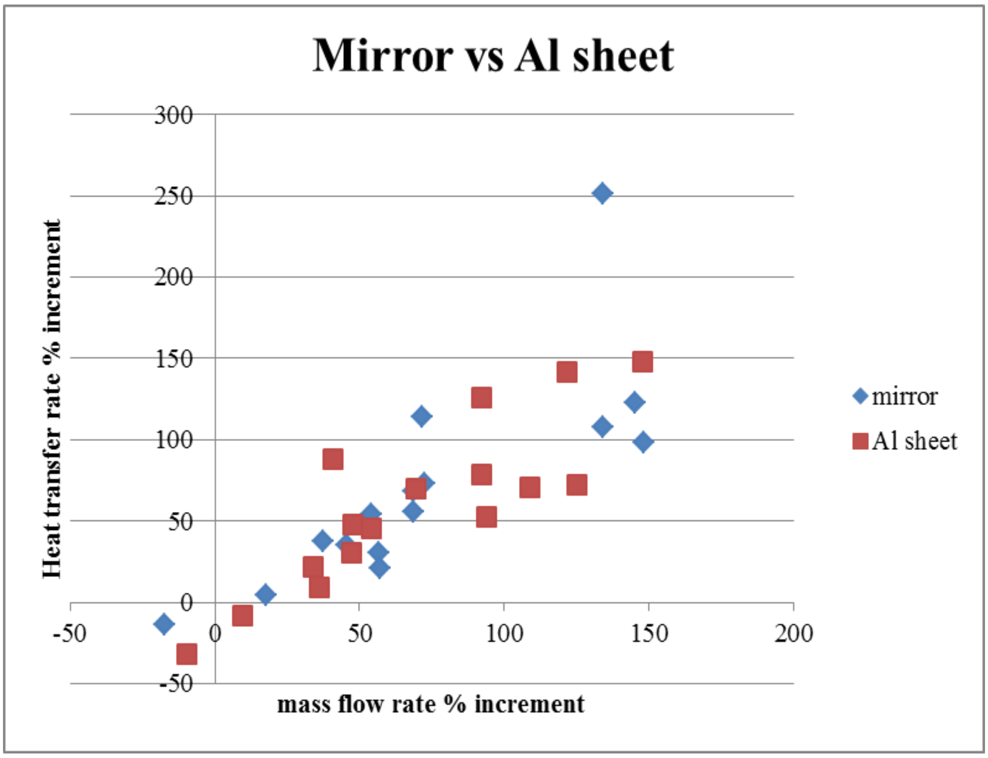

Figure 5. Graph plotted between % increment of mass flow rate and % increment in heat transfer rate for mirror and aluminium collector

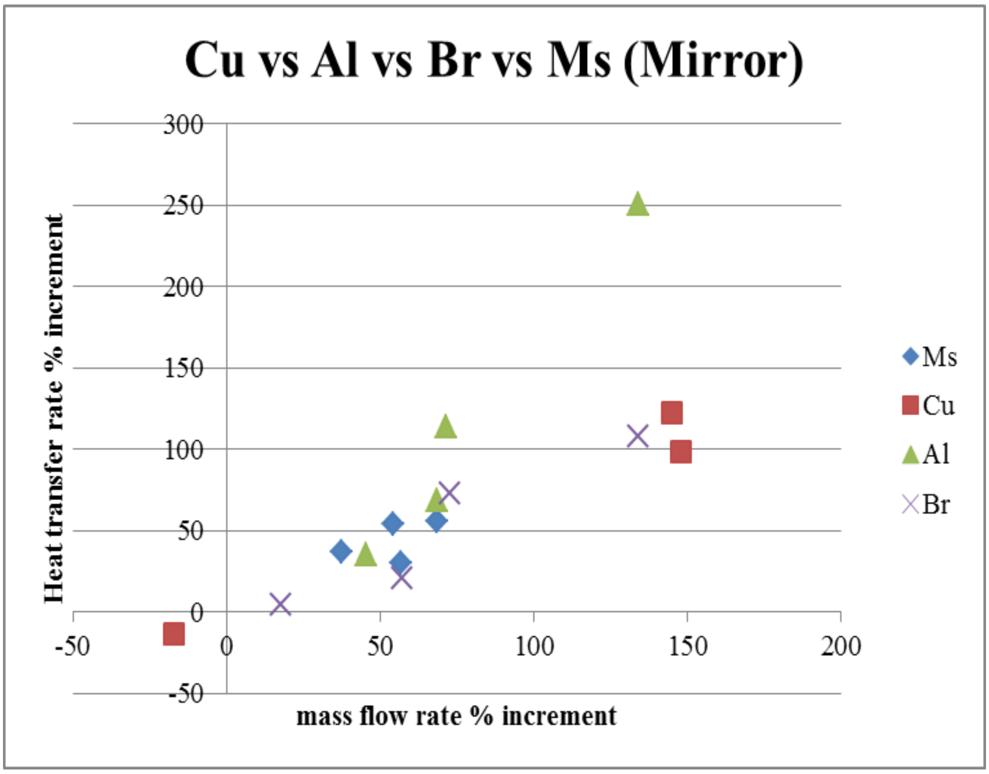

Figure 6. Graph plotted between % increment of mass flow rate and % increment in heat transfer rate for various materials with mirror collector

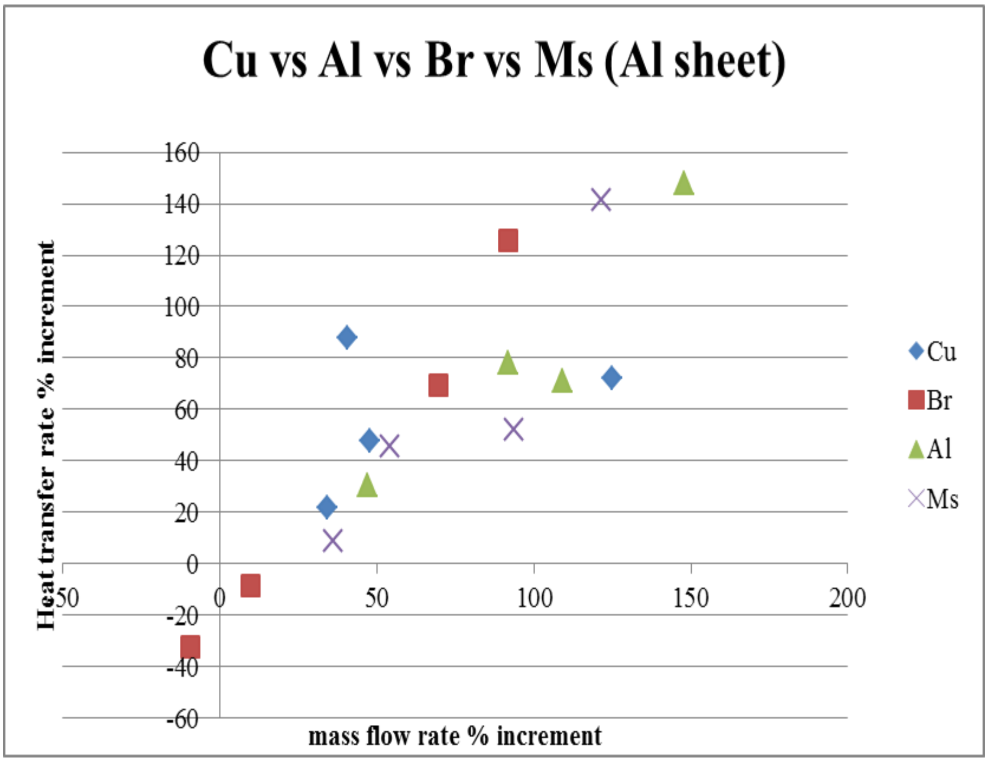

Figure 7. Graph plotted between % increment of mass flow rate and % increment in heat transfer rate for various materials with aluminium sheet collector

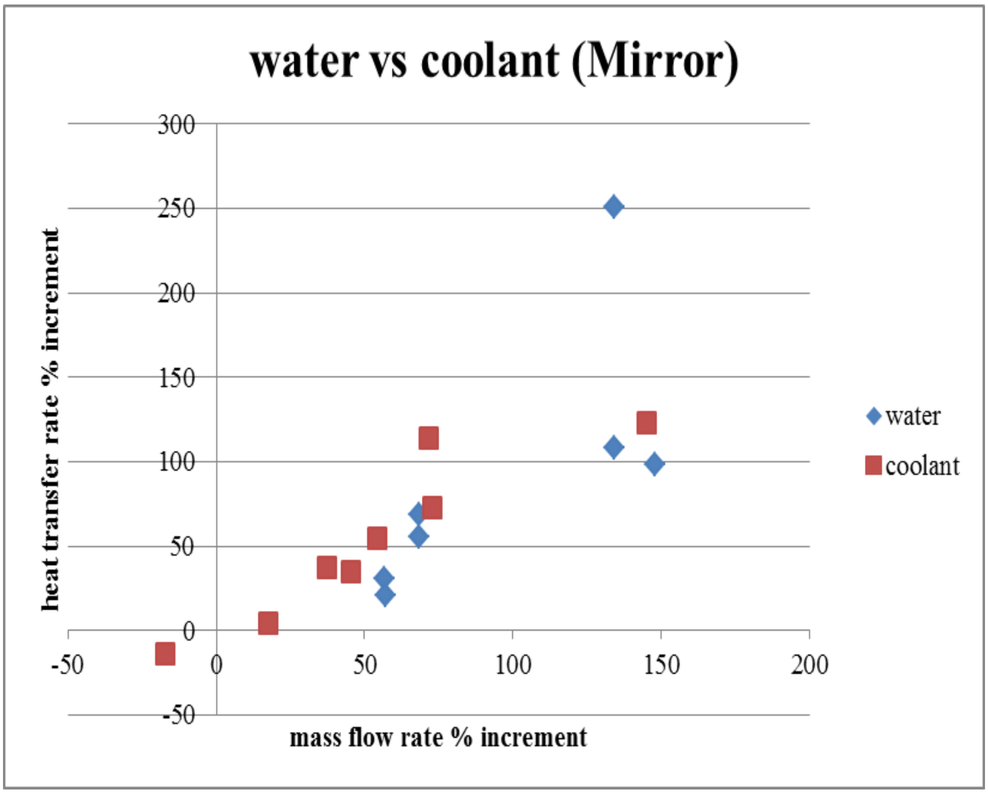

Figure 8. Graph plotted between % increment of mass flow rate and % increment in heat transfer rate with various flowing fluids for mirror collector

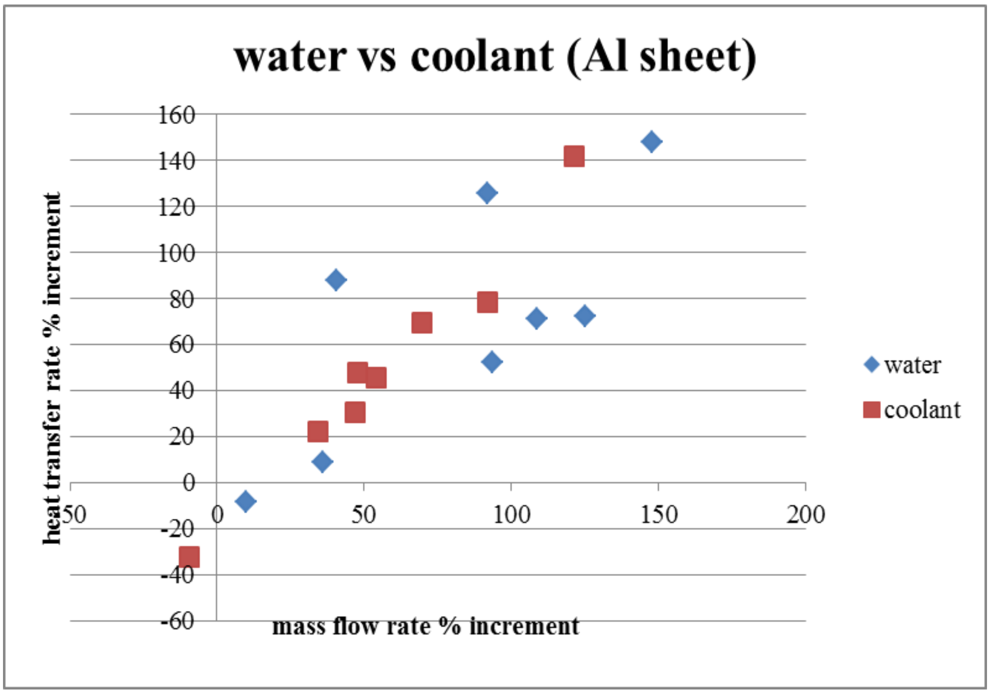

Figure 9. Graph plotted between % increment of mass flow rate and % increment in heat transfer rate with various flowing fluids for aluminium sheet collector

4. Conclusions

In this experimental work, lots of measurements have been taken on the two parabolic solar collectors, namely a mirror collector and an aluminium sheet collector. Outlet temperatures, heat transfer rates and instantaneous efficiencies have been recorded with combinations of two water/coolant flowing fluids and four pipe materials and optimized performance of solar collectors are determined. Through the experimentation, maximum heat transfer rate and maximum instantaneous efficiency of the collector have been identified. The conclusion is that the maximum instantaneous efficiency of 92% is achieved at 12:30PM with aluminium pipe-water combination through aluminium sheet collector. The maximum heat transfer rate of 1208.99W is achieved at 01:30PM with copper-antifreeze ethylene glycol through mirror collector. Furthermore, the maximum temperature difference of 12.2 ºC is achieved at 12:30PM with copper-water combination though aluminium sheet collector. With the help of graphical analyses, this experimental study concludes copper is the best pipe materials. And, antifreeze ethylene glycol coolant with copper pipe would absorb more heat than water. The reflection of solar energy to the absorber pipe via aluminium sheet collector is better than mirror collector. The conclusions are useful for future improvement in the performance of parabolic solar collectors.

Acknowledgements

This research work is done at Sushila Devi Bansal College of Technology, Indore, Madhya Pradesh, India. Fabrication of parabolic solar collector is done by research scholar.

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